Committee on Resources

Full Committee

Testimony

STATEMENT BY JOHN MAURO BEFORE THE COMMITTEE ON RESOURCES
REGARDING THE STATUS OF NUCLEAR CLAIMS, RELOCATION,
AND RESETTLEMENT EFFORTS IN THE MARSHALL ISLANDS

This statement was prepared by Dr. John Mauro as an employee of Sanford Cohen & Associates (SC&A), Inc. of McLean, Virginia. On October 16, 1998, SC&A was retained by the People of Enewetak by the Enewetak/Ujelang Local Government Council ("Council") of the Republic of the Marshall Islands to assist the Council with respect to radiological issues concerning the remediation, restoration, and resettlement of Enewetak Atoll. Specifically, SC&A performed the following investigations:

1. An evaluation of the potential radiation doses and radiological health risks to populations on Enewetak Atoll due to radioactive contamination of the environment from weapons-testing. The results of the evaluations were compared to the radiation protection criteria used in the U.S. for the cleanup of sites contaminated with radioactive materials, and adopted by the Nuclear Claims Tribunal for use by the Republic of the Marshall Islands; and

2. An evaluation of the costs associated with the remediation of the Islands to the U.S. cleanup criteria using several alternative remediation strategies. The evaluation included a recommended remediation strategy and its associated costs.

My statement today addresses these two topics.

BACKGROUND

SC&A began work on behalf of the Council in September 1998 following a meeting at the Embassy of the Republic of the Marshall Islands (RMI). In attendance at that meeting were Senator Ismael John, Mayor Neptali Peter, Franco Matearikí, Davor Pevec, Allan Richardson, and myself. During that meeting, we discussed a broad range of issues, including previous work performed by the Department of Energy, the current radiation protection and cleanup criteria being employed in the RMI and in the U.S., the remediation alternatives currently under consideration for Enewetak Atoll, especially the application of potassium chloride (KCl), and a number of other topics pertaining to the history, cleanup, and resettlement of Enewetak Atoll. Following that meeting, SC&A prepared a work plan for providing technical and regulatory support related to the radiological issues associated with resettlement. The plan was subsequently approved by the Council.

Our work consisted of two parallel efforts. The first consisted of support to Allan Richardson and Davor Pevec on technical matters related to the choice of cleanup criteria applicable and appropriate to the Marshall Islands. The outcome of these activities was a ruling by the Nuclear Claims Tribunal (NCT) that adopted the U.S. EPA cleanup criteria applicable to the vast majority of radioactive contamination in the United States, and includes the dose criterion of 15 mrem/yr EDE to the individuals that have the potential to receive the reasonable maximum exposure (RME). The second consisted of a series of investigations into the potential radiation doses and health risks to resettled populations on Enewetak Atoll and the costs and effectiveness of a full range of alternative remediation strategies designed to reduce these exposures and potential health risks to acceptable levels.

The results of SC&A's investigations pertaining to radiation doses, risks, and remediation strategies were provided to the Council in March 1999 in a document entitled, "Part 1 - Statement Before the Nuclear Claims Tribunal Regarding the Potential Radiation Doses and Health Risks to a Resettled Population of Enewetak Atoll and an Evaluation of the Costs and Effectiveness of Alternative Strategies for Reducing the Doses and Risks," March 23, 1999. A copy of the Statement has been provided to the Committee under separate cover. I served as the Project Manager and Principal Investigator for the preparation of the Statement to the Tribunal and authored those sections dealing with radiation doses and risks. Dr. Hans Behling, also with SC&A, authored those portions of the Statement dealing with alternative remediation strategies and their costs. During the week of April 12, 1999, Dr. Hans Behling and I provided testimony at a hearing of the Nuclear Claims Tribunal addressing the information contained in the Statement.

Our investigations consisted of four parts: (1) characterization of the radiological conditions on Enewetak Atoll, (2) evaluation of the radiological doses and health risks associated with resettlement of the atoll, assuming no further remediation, and comparing these doses and risks to cleanup criteria adopted by the NCT, (3) evaluation of collective health impacts under various remedial alternatives, and (4) evaluation of alternative remediation strategies and their costs for reducing exposures to the cleanup criteria.

Our approach to the project was to use existing data and reports characterizing the radiological conditions of the islands, the dose and risk assessment methodologies recommended by the EPA and used in the U.S. for the cleanup of Federal facilities, and both published and unpublished information regarding the types and costs of alternative remediation strategies.

Our overall objective was to identify remediation strategies that are:

> 1. protective of public health and the environment, 2. compatible with efforts to establish a self-sustainable ecosystem by minimizing ecological damage, and 3. cost-effective.

STATEMENT REGARDING RADIATION DOSES AND HEALTH RISKS

Data Sources

In performing our investigations, SC&A did not collect environmental samples or perform radiochemical analyses of environmental samples. Such analyses were neither possible, nor necessary, given the scope and schedule of the project and the significant quantity of radiological data and reports that have been compiled in the past by several U.S. government agencies, under the direction of Dr. William Robison, and by the Marshall Islands Nationwide Radiological Survey performed under the direction of Dr. Steven L. Simon and James C. Graham. Instead, we collected and reviewed the available data and reports and developed our own understanding of the radiological conditions of the atoll.

Objectives

Using these data, we pursued three objectives with respect to dose/risk assessment:

- replicate the individual radiation dose estimates obtained by Lawrence Livermore Laboratory (LLL),
- derive average and high-end individual dose rates in accordance with U.S. EPA methodologies and assumptions, and
- derive the potential time-integrated collective health impacts to a resettled population on Enewetak Atoll.

Replication of the LLL Analyses We decided that it would be prudent to attempt to replicate the radiation dose assessments performed by Dr. William Robison of Lawrence Livermore Laboratory before we performed our own calculations. Our review of the literature revealed that Dr. Robison has been investigating the radiological conditions of the Marshall Islands, including Enewetak Atoll, for many years, and has performed several detailed doses assessments of Enewetak Atoll. In a dose assessment performed for the island of Enjebi of Enewetak Atoll[(1)], Dr. Robison estimated that the peak annual radiation dose to a typical member of a population that might resettle Enjebi in the future would be about 169 mrem/yr effective dose equivalent (EDE), and that most of this dose would be due to Cs-137 in locally grown foods. Using the same modeling assumptions, we derived a dose of 145 mrem/yr EDE. We believe that the primary reason for the differences in the analyses (which we consider relatively small) is that the Robison analysis derived dose conversion factors using the methods described at the time by the International Commission on Radiation Protection (ICRP), while we used the dose conversion factors recommended by the U.S. EPA, which are an update of the ICRP dose conversion factors. Based on this analysis, we believe that we understand the methods, data, and assumptions used by Robison. We considered this exercise useful because it established a point of departure for the analyses that followed.

Derivation of High-End Doses and Risks

The next step in our evaluations consisted of reassessing the doses using assumptions that are more compatible with the EPA approach to the assessment of radiation doses and risks for the protection of members of the general public due to radioactivity in the environment. The EPA has developed a comprehensive set of standards and implementation protocols, under several environmental statutes, that are designed to protect members of the public from hazardous chemicals and radioactive materials in the environment. The statute most applicable to the issues of concern here is the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also referred to as Superfund. The main objective of Superfund is to assure cleanup of sites contaminated with hazardous material to acceptable levels and the return of the property to a condition suitable for unrestricted use.

As indicated above, the dose assessment presented by Robison is concerned primarily with estimating doses to the average member of the Enjebi population in the year in which the peak dose is projected to occur. Though the EPA makes use of average doses for some purposes, when establishing requirements for cleanup, it places primary reliance on the doses and risks associated with the reasonable maximum exposure of individuals. EPA 1989[(2)] states that:

> "*... actions at Superfund sites should be based on an estimate of the reasonable maximum exposure (RME) expected to occur under both current and future land use conditions. The reasonable maximum exposure is defined here as the highest exposure that is reasonably expected to occur at a site... The intent of the RME is to estimate a conservative exposure case (i.e., well above the average) that is still within the range of possible exposures.*"

Additional guidance provided in EPA 1992[(3)] states the following:

"*Information about individual exposure and risk is important to communicating the results of a risk assessment. Individual risk descriptors are intended to address questions dealing with risks borne by individuals within a population. These questions can take the form of:*

- *Who are the people at the highest risk?*
- *What risk levels are they subjected to?*
- *What are they doing, where do they live, etc., that might be putting them at higher risk?*
- *What is the average risk for individuals in the population?*

The high-end of the risk distribution is, conceptually, above the 90th percentile of the actual (either measured or estimated) distribution. The conceptual range is not meant to precisely define the limits of this descriptor, but should be used by the assessor as a target range for characterizing "high-end risk."

Given the above general EPA guidelines, it can be concluded that, although the dose assessment provided by Robison is useful for characterizing the doses to an average member of the population, it does not fully address the high-end doses and potential health risks. In our Statement to the Tribunal, we presented an assessment of the potential high-end doses and health risks associated with a range of different life styles and dietary patterns, assuming that the people of Enewetak Atoll resettle the islands with no further remediation of the residual contamination. We refer to this type of an analysis as a "baseline dose and risk assessment." The baseline dose and risk assessment is used to determine if, and the degree to which, additional remediation and/or institutional controls are needed prior to or during resettlement of individual islands in order to ensure compliance with the designated cleanup criterion of 15 mrem/yr EDE to the RME individual.

Clearly, there is room for interpretation of what, in fact, constitutes a reasonable high-end estimate of doses and risks to future residents of the currently unoccupied islands of Enewetak Atoll. Two independent sets of modeling assumptions are required in order to determine the high-end doses and health risks attributable to the RME individual:

> (1) the diet and living habits of the RME individual (which we refer to as the "exposure" scenarios), and
>
> (2) the radionuclide concentrations in the environment and in the food items at the high-end locations on each of the islands (which we referred to as the "source" scenarios).

Based on our review of different diets reported in the 1987 Robison report and summarized in a report by the National Academy of Sciences[(4)], and consultation with Dr. Laurence Carucci and Ms. Mary Maifeld[(5)], we elected to evaluate the doses for a range of diets. For the average individual, we elected to use the diet described in the Robison 1987 report as the "local plus imported diet," which consists of 3003 Kcal/d, of which only 512 Kcal/d is local. For the high-end individual, we elected to use two different local-only diets described in NAS 1994; one consisting of a low caloric diet of 1254 Kcal/day and the other consisting of a high caloric diet consisting of 3208 Kcal/day of entirely locally harvested foods. We assumed that the latter diet would not begin until the year 2010, while the others could begin as early as the year 2000.

Inspection of the data characterizing the radionuclide concentrations in soil on each of the islands of Enewetak Atoll revealed that the radionuclide concentrations vary considerably from one location on an island to another. As a result, the doses to an individual household could vary considerably depending on household location. Using several statistical and geographical analytical methods, we determined that the doses to a household located at a high-end location on a given island could be about three times greater than for households located at average locations on that island.

The consequences of using high-end assumptions regarding diet and household location has a profound effect on the results of the analysis. As compared to an analysis of the average doses, the high-end doses are up to a factor of about six-fold higher as a result of dietary assumptions, and another factor of three-fold higher as a result of assumptions regarding the radionuclide concentrations at high-end locations. The overall effect is that the high-end doses can be about 18-fold higher than the average doses. Table 1 presents the results of the analysis of the baseline dose assessment for both the average and high-end individuals for the various islands of Enewetak Atoll. The islands in **bold** will require some form of remediation in order to meet the 15 mrem/yr EDE cleanup criterion.

Table 1. Average and high-end doses on islands of Enewetak Atoll

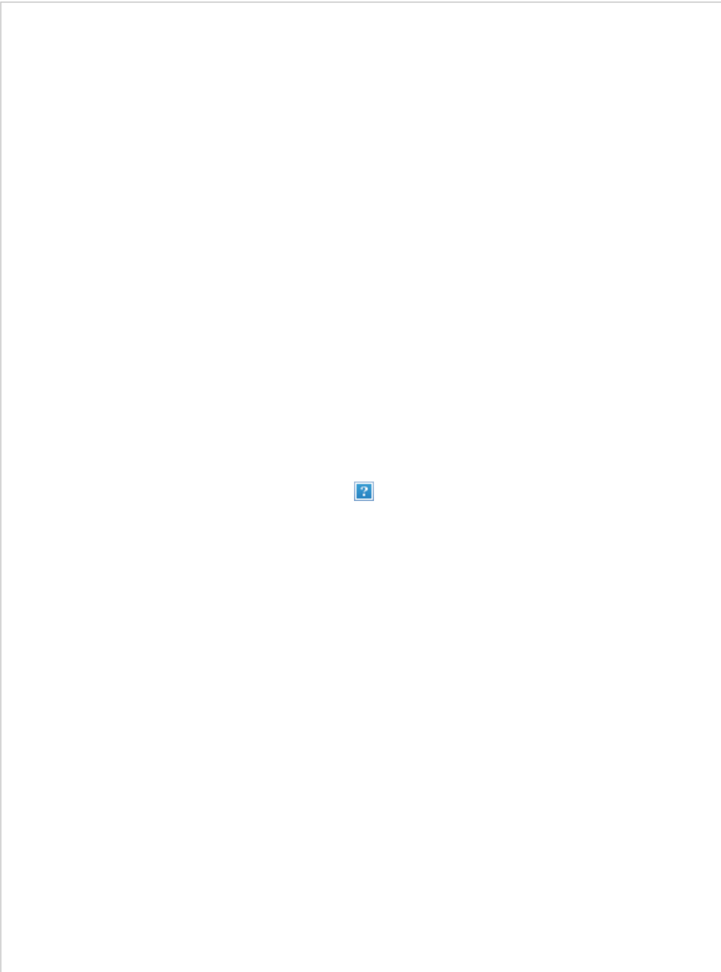
Island	**Average Dose** (year 2000 using the Robison imported plus local diet and average location)[a]	**High-End Dose** (year 2000, high-end location, Robison 1987 local-only diet (1254 Kcal/d) [b]	**High-End Dose** (year 2010, 3208 Kcal/d, local-only diet (3208 Kcal/d) [c]
Enjebi*	**96**	**528**	**1355**
Aej	**42**	**246**	**632**
Lujor	**48**	**179**	**460**
Aomen	**24**	**94**	**242**
Bijire	**24**	**96**	**247**
Lojwa	**16**	**60**	**154**
Alembel	**32**	**102**	**262**
Ananij	3	10	26
Japtan	3	12	31
Medren	2	8	21
Enewetak	2	7	18
Runit	**8**	**43**	**111**
Billae	**11**	**57**	**146**

Elle	**107**	**548**	**1408**
Bokenlab	**31**	**173**	**445**
Kidrinenen	**34**	**194**	**499**
Mijikadrek	**23**	**127**	**326**
Boken	**22**	**113**	**290**
Bokinwotme	**19**	**97**	**249**
Louj	**30**	**152**	**391**
Bokoluo	**400**	**2220**	**5705**
Bokombako	**219**	**1170**	**3007**
Kirunu	**104**	**584**	**1501**
Biken	**9**	**49**	**126**
Ikuren	**3**	**14**	**36**
Kidrenen	1	6	15
Ribewon	0	1	2
Inedral	0	2	4
Van	1	5	12
Mut	**4**	**19**	**49**

* Islands in bold require remediation a. Includes Cs-137 in ubiquitous background, which contributes up to about 1 mrem/yr. b. Includes Cs-137 in ubiquitous background, which contributes up to about 2 mrem/yr. c. Includes Cs-137 in ubiquitous background, which contributes up to about 5 mrem/yr. Our evaluations reveal that, should the population of Enewetak Atoll resettle the northern islands without any additional remediation of the contaminated soil or the implementation of institutional controls, radiation doses to large segments of the population could be several hundred mrem/yr effective dose equivalent (EDE), and, at some locations, exposures could exceed several thousand mrem/yr EDE. The potential lifetime risk of cancer due to these exposures could be as high as six chances in one hundred for individuals who reside at the more highly contaminated locations and obtain most of their foods from the atoll. These radiation exposures far exceed the EPA radionuclide cleanup criterion of 15 mrem/yr EDE to individuals that are anticipated to receive high-end exposures. In addition, the projected lifetime health risks far exceed the EPA risk criterion of no greater than one in ten thousand. Collective Health Impacts In addition to assessing the radiation doses and health risks to individuals, we also evaluated the number of serious health effects that could be experienced by resettled populations of Enewetak Atoll in the future due to the levels of radioactive contamination currently in the environment (i.e., the baseline impacts) and following selected remediation alternatives designed to reduce the exposures. We use the term "health detriment" for this quantity. The health detriment, as defined in our analyses, is the time-integrated, collective health impacts that may be experienced by a resettled population due to residual radioactivity in the environment. The term "collective" is used because the analysis provides an estimate of the total number of serious health effects (primarily cancer) that may occur in the exposed population. The term "collective" distinguishes this analysis from analyses that are concerned with the additional risk to an individual over his or her lifetime (which is addressed above). The term "baseline" is used to refer to the potential impacts on the population under the current radiological conditions of the islands. A baseline analysis distinguishes pre-remediation impacts from the potential impacts following remediation of the contamination or the application of other controls designed to reduce exposures. Since some radionuclides will be present in the environment for a relatively short period of time, while others will be present for many thousands of years, it is instructive to evaluate the collective health detriment over different time periods. In this analysis, the time periods chosen were 10, 100, 1000, and 10,000 years. The term "integrated" is the mathematical term used for "sum" when performing these types of calculations. The approach used to derive the baseline collective health detriment consisted of deriving the average radiation exposure to the average individual on each island in the first year of each time period of interest, multiplying that value by the number of people on the island during that time period, and then integrating the exposure over the time period. This results in the time-integrated collective exposure for each time period. This parameter is then converted to health risk using EPA risk coefficients. The results indicate that, assuming resettlement in the year 2000, and if no additional cleanup, remedial measures, or institutional controls were implemented, the projected radiological health detriment on the population due to the current levels of radionuclide contamination would be about 7 serious health effects over the first 100 year period (year 2000 to 2100) and about 9 serious health effects over a 1000 year time period (year 2000 to 3000). An assessment of the collective health detriment is useful because it provides an estimate of the potential health impacts that may be experienced by a resettled population and future generations prior to and following alternative remediation strategies. It is also helpful in the development of compensation schemes associated with the projected health impacts. Specifically, the EPA has proposed that investments in remediation of a site can be monetized at a rate of $2 million to $15 million, with a best estimate of $5.8 million per statistical serious health effect averted by a given remediation alternative.[(6)] This is the range of dollar values EPA proposes to assign to a statistical life in support of the development of environmental standards. Therefore, on this basis, it could be argued that society should be willing to invest between $18 million to $135 million, with a best estimate of $52 million, to avert the projected serious adverse health impacts associated with residual radioactivity in the Enewetak Atoll. It should be noted that such assessments are based on cost/benefit arguments and do not take into account individual equity considerations, such as the one in ten thousand risk criterion that forms the basis of the EPA cleanup standard. Relevance of Findings The dose and risk assessments performed by SC&A are in many ways similar to the analyses performed by Lawrence Livermore Laboratory (LLL). However, our analyses differ from those of LLL with respect to several important issues, including: 1. Our analyses explicitly address the high-end individuals, which result in doses that are over 10 times higher than the doses derived by LLL for the average individual; 2. Our analyses address both health risks to individuals and the collective health burden on the exposed population. Analyses performed by LLL did not explicitly address these issues; 3. SC&A evaluated the results of the dose and risk assessment in terms of compliance with EPA's 15 mrem/yr EDE cleanup criterion[(7)] and the lifetime risk criterion of one in ten thousand[(8)] for high-end individuals. These criteria differ markedly from the cleanup criterion of 170 mrem/yr for the average individual cited by LLL. The results of our analyses revealed that, if the Marshall Islands were a state in the U.S., resettlement of the northern islands of Enewetak Atoll would not be permitted under EPA criteria without extensive remediation and/or institutional controls. 4. The significance of these results are that the remediation methods required to achieve compliance with the EPA criteria must be much more aggressive than those identified by LLL for achieving compliance with the LLL cited criteria. Specifically, our results reveal that the application of potassium to soil[(9)] cannot, by itself, reduce Cs-137 in food crops to the level required to achieve compliance with the more stringent EPA cleanup criterion of 15 mrem/yr EDE to the RME individual that was adopted by the Nuclear Claims Tribunal. 5. The results of the analysis of the collective health detriment reveal that the residual levels of radioactive material in the environment have the potential to cause about nine serious health effects over the next 1000 years if Enewetak were resettled with no further remediation or the implementation of institutional controls. Using EPA's proposed cost/benefit criterion, avoidance of this potential detriment at a cost of up to $135 million would be considered to be cost/effective. EVALUATION OF ALTERNATIVE CLEANUP STRATEGIES In light of these findings, we conclude that substantial remediation is required for most of the northern islands of Enewetak Atoll. Estimates of costs were prepared for three remediation alternatives designated as Case #1, Case #2, and Case #3. Each of these remediation alternatives is designed to meet the 15 mrem per year dose limit. In order to develop the cost estimates for each alternative remediation strategy, we drew heavily from previous cost analyses performed by the Bikini Atoll Rehabilitation Committee (BARC). Case #1 consists of the removal of all soils with Cs-137 concentration levels in excess of 0.37 pCi/g, which corresponds to 15 mrem/yr EDE above background to the RME individual. The volume of soil requiring removal is estimated to be about 1.9 million cubic meters. Case #1 provides maximal assurance that future exposures would not exceed the prescribed dose limit of 15 mrem per year EDE above background, but would have the most severe ecological consequences. An ecologically less harmful remediation strategy is defined by Case #2. Soil-removal quantities under this approach are reduced to about 468,000 cubic meters, or about one-fourth the volume defined for Case #1. This large reduction in volume is achieved by taking credit for the reduction in dose due to (1) the dilution effect of clean backfill within the root zone of food crops and (2) the associated shielding that reduces external exposure. Case # 3 uses a combined approach involving both soil removal and soil treatment with potassium. For Case # 3, soil removal is reduced to an estimated volume of 223,000 cubic meters. This case achieves the least environmental disruption of the three remediation strategies. The primary cost elements associated with each of these three alternative remediation strategies include radiological survey costs, soil removal and/or treatment, disposal of contaminated soil as low-level radioactive waste, and the long-term rehabilitation/restoration of soil. At a glance, these remediation tasks give the appearance of being commonplace. However, their execution is complicated and made difficult by geophysical factors and the remoteness of Enewetak Atoll that currently includes uninhabited islands. For most of the islands that are earmarked for cleanup and resettlement, there is either no or only a limited existing infrastructure required to support remediation (e.g., piers for loading/unloading heavy equipment, materials, personnel, etc.; intra-island roads; electricity, potable water, housing, sanitation, etc.; field laboratory and other radiological support facilities; a trained and qualified remediation local workforce). Not surprisingly, it is these aspects that are key factors for defining costs. In deriving cost estimates, we drew heavily from data contained in reports published by the AEC[(10)], DOE[(11)], and DNA[(12)] regarding similar surveillance and cleanup efforts conducted at Enewetak Atoll between 1972 and 1980. Equally important were data involving projected costs contained in a series of reports issued by the Bikini Atoll Rehabilitation Committee (BARC)[(13)] The cost analysis for each alternative addresses five soil disposal options and two soil/agricultural rehabilitation options. Thus, for each of the three remediation alternatives, we evaluated 10 options, for a total of 30 different remediation combinations. In addition, all cases include the costs for radiological controls around the Cactus Dome on Runit and the costs for the cleanup of plutonium contamination in the Fig/Quince area of Runit.[(14)] Figure 1 summarizes the results of these analyses. The costs range from a low value of $70.9 million for Case # 3 using lagoon dumping as the soil disposal method and the agricultural soil rehabilitation option, to a high value of $973.9 million for Case #1 using soil disposal in a crater with dome (similar to the Cactus Dome on Runit) and the imported topsoil method for soil rehabilitation. Following our review of each alternative and option, and discussions with the people of Enewetak Atoll, we recommend a remediation program consisting of a combination of soil removal and application of potassium to soil as an integral part of a self-sustaining, agricultural rehabilitation program (i.e., Case # 3). We also recommend that the removed soil be used as fill material for construction of a causeway connecting Enewetak to Medren. The total cost for this combined program, including soil disposal and all supporting elements, is estimated to be $100.1 million. Applying a 15% contingency, our recommended remediation strategy is estimated to cost about $115 million. Given the collective health detriment associated with resettlement under baseline conditions and the range of values assigned to a statistical life, as described above, Case #3, using causeway disposal and agricultural rehabilitation, at a

cost of $115 million, appears to be the most: 1. Feasible regarding implementation, 2. Protective of public health and compliant with the dose limit of 15 mrem per year, 3. Compatible with efforts to establish a self-sustainable soil/ecosystem, and 4. Cost-effective.

Figure 1. Summary of remediation cost analysis



Listing of all Federal Grants or Contracts Received by SC&A since 10/1/94

Prin

SC&A#	Agency	Start Date	End Date	Contract#	Client	
AEHP	U.S. AID	6/21/95	9/24/98		CDM International, Inc. 1611 N. Kent Street, #1001 Arlington, VA 22209	Sub
AEOHS	DOE	10/10/95	3/12/98		Univ. of Med. & Dentistry of NJ Environmental & Occupational Health Sciences Institute 681 Frelinghuysen Road P.O. Box 1179 Piscataway, NJ 08855	Sub
AET01	COE	9/20/96	7/31/97	97S-0012-SB4	Earth Tech 1461 East Cooley Dr., Suite 100 Colton, California 92324	Sub
AHUNT	COE	4/17/95	4/16/2000	HUNT-02	Parsons Engineering Science Inc. 57 Executive Park S., NE, #500 Atlanta, GA 30329	Sub
BDYN1 BDYN2 BDYN3	EPA	9/15/97	9/14/2002	5150-909	DynCorp I&ET, Inc. 12750 Fair Lakes Circle Fairfax, VA 22033	Sub
BHYD1 BHYD2 BHYD3	EPA	9/22/97	9/30/2000	EPA005F	HydroGeoLogic, Inc.	Sub
BOER	EPA	8/06/96	7/22/2001	EMS S06-W6-0046	Environmental Management Support, Inc. 861 Georgia Avenue, #500 Silver Spring, MD 20910	Sub
BORD	EPA	9/1/95	8/31/96	95-006-02	Environmental Management Support, Inc. 861 Georgia Avenue, #500 Silver Spring, MD 20910	Sub
CRDN1 CRDN2 CRDN3	EPA	12/31/97	12/31/2000	68D98007	U.S. Environmental Protection Agency Research Triangle Park, NC 27711	Prin
CWST1 CWST2 CWST3	EPA	9/24/97	9/30/2000	68D70073	U.S. Environmental Protection Agency Research Triangle Park, NC 27711	Prin
FAPG1	COE	1/7/97	3/7/97	7102-97S-4713	Foster Wheeler Environmental Corp. 8 Peach Tree Hill Rd. Livingston, NJ 07039	Sub
FAPG2	COE	5/6/97	??	Sub. No. 001990	Foster Wheeler Environmental Corp. 8 Peach Tree Hill Rd. Livingston, NJ 07039	Sub
FBLM	DOI	5/15/97	4/15/98	1422-N660-C97-3052	U.S. Dept. of the Interior Bureau of Land Management Denver Federal Center, Bldg 50 Denver, CO 80225-0047	Prin
FCMC	COE	2/27/98		DACA87-98-P-0116	U.S. Army Engineering & Support Center ATTN: CEHNC-CT-S/D. Wolaver P.O. Box 1600 Huntsville, AL 35805-4301	Prin
FDOD	DoD	4/22/97	7/05/97	P.O. # MDA410-97-P-0103	DoD Education Activity Procurement Division 4040 North Fairfax Dr. Arlington, VA 22203-1635	Prin
FDRI		1/10/99	4/10/99	4009.001.01 Work Auth. # 001	EOD Technology, Inc. 10938 Hardin Valley Road Knoxville, Tennessee 37932	Sub
FEA1		11/04/97	11/18/97	PO17201	EA Engineering 11019 McCormick Rd. Hunt Valley, MD 21031	Sub
FEHSI	COE	8/21/97	12/12/1999	Unnumbered Subcontract	Environmental Hazards Specialists Int'l, Inc. Rt. 1, Box 232 Belvidere, NC 27919	Sub
FEOD		11/24/98	11/24/98	PO# 3619	EOD Technology, Inc. 10938 Hardin Valley Road Knoxville, TN 37932	Sub
FERG	EPA	8/19/98	8/21/98	0076.02.021.019	Eastern Research Group 110 Hartwell Avenue Lexington, MA 02173-3134	Sub
FGER		3/1/99	4/30/99	PO# WC1JUW-9057-0322	U.S. Army Engineer District, Alaska CEPOA-CT P.O. Box 898 Anchorage, AK 99506-0898	Prin
FHORN		7/27/98	11/30/98	PO#98-3050-0067-2	Horne Engineering Services 2750 Prosperity Ave., Suite 450 Fairfax, VA 22031	Sub
FJPG4	NAVY	11/01/97	10/31/98	S0075-97-UXO-JPG4-004	Tetra Tech EM Inc. 1593 Spring Hill Road, Suite 300 Vienna, VA 22182	Sub
FKH1		3/14/97	ongoing	KH700325EP6-DPT-072-97	Kaiser Hill Company, LLC	Sub
FKNOW	COE	7/8/96	7/7/99	DACA87-96-D-0022	U.S. Army Corps of Engineers Huntsville, AL	Prin
FMARE	Navy	10/16/98	11/11/98	6130.003	Environmental Chemical Corporation 1240 Bayshore Highway Burlingame, CA 94010	Sub
FORAU		7/29/98	8/21/98	14C-80623	Oak Ridge Associated Universities P.O. Box 117 Oak Ridge, TN 37831-0117	Sub
FPRC	COE	9/17/96	11/30/96	S0075-96-UXO-012	PRC Environmental Management 1593 Spring Hill Road, #300 Vienna. VA 22182	Sub
FRMA		5/1/98	3/31/99	010519	Foster Wheeler Environmental Corporation c/o Rocky Mountain Arsenal - PMC 72nd Ave. at Quebec Street Trailer Z-96 Commerce City, CO 80022-1748	Sub
FRMA2		1/14/99	9/30/2002	015535	Foster Wheeler Environmental Corporation c/o Rocky Mountain Arsenal - PMC 72nd Ave. at Quebec Street Trailer Z-96 Commerce City, CO 80022-1748	Sub
FSAIC	DOE	7/29/96	7/31/97	4500061520	SAIC 800 Oak Ridge Turnpike P.O. Box 2502 Oak Ridge, Tennessee 37831	Sub
FSVER		11/9/98	11/9/98	000222-01	Sverdrup Environmental, Inc. 13723 Riverport Drive Maryland Heights, MO 63043	Sub
FUSGS	USGS	7/15/98		98WRSA1294	U.S. Geological Survey	Prin
FUTIL		9/09/98	10/1/98	013355	Foster Wheeler Environmental Corporation c/o Rocky Mountain Arsenal - PMC 72nd Ave. at Quebec Street Trailer Z-96 Commerce City, CO 80022-1748	Sub
FWET	EPA	3/1/97	2/28/2000	68C70003	U.S. EPA 4411 Montgomery Rd, Suite 300 Norwood, OH 45212	Prin
FZAP1	COE	7/20/98	11/99	Unnumbered Subcontract	Zapata Engineering 1100 Kenilworth Avenue Charlotte, NC 28204	Sub
FZAP1 (add-on)	COE	3/22/99	11/99	98-2303	Zapata Engineering 1100 Kenilworth Avenue Charlotte, NC 28204	Sub
FZAP2	COE	7/21/98	11/99	Unnumbered Subcontract	Zapata Engineering 1100 Kenilworth Avenue Charlotte, NC 28204	Sub
HCDM	U.S. AID	6/95	9/24/98	3037SC&A	Camp Dresser & McKee 1611 N. Kent Street, #1001 Arlington, VA 22209	Sub
HCULE	ARMY	5/03/96	TBD	3195803G	Environmental Science and Engineering	Sub
HDIX	ARMY	1/7/98	2/6/98	007759	Foster Wheeler Env. Corp. 8 Peach Tree Hill Road Livingston, NJ 07039	Sub

HEA3	ARMY	2/5/98	2/23/98	003442	EA Engineering, Science, & Technology 11019 McCormick Road Hunt Valley, MD 21031	Sub
HEEG5	DOE	7/01/96	10/31/96	EEG-0075	Environmental Evaluation Group 505 N. Main Street P.O. Box 3149 Carlsbad, NM 88221	Sub
HEEG6	DOE	8/28/96	10/31/96	EEG-0077	Environmental Evaluation Group 505 N. Main Street P.O. Box 3149 Carlsbad, NM 88221	Sub
HEEG7	DOE	12/2/96	1/15/97	EEG-0081	Environmental Evaluation Group 505 N. Main Street P.O. Box 3149 Carlsbad, NM 88221	Sub
HEEG8	DOE	1/06/97	2/15/97	EEG-0082	Environmental Evaluation Group 505 N. Main Street P.O. Box 3149 Carlsbad, NM 88221	Sub
HESE	COE	8/19/96	9/19/96	3195165G-0600-3100	Environmental Science & Engineering, Inc. P.O. Box 1703 Gainesville, FL 32602	Sub
HFOST		3/2/95	5/97	7102.95S-2036	Foster Wheeler Corporation 9 Peach Tree Hill Road Livingston, NJ 07039	Sub
HGER		9/11/97	10/30/97	DACA85-97-P-0244	U.S. Army Engineering District CEPOA-CT P.O. Box 898 Anchorage, AK 99506-0898	Prin
HGPI		2/5/99		PO# 98035-2599	Gutierrez-Palmenberg, Inc. 2922 W. Clarendon Avenue Phoenix, AZ 85017	Sub
HHGL		3/6/98	12/23/99	AFC001U	HydroGeoLogic, Inc. 1155 Herndon Parkway, Ste. 900 Herndon, VA 20170	Sub
HHOPE	COE	11/9/98	5/15/99	HAL9811009	American Technologies, Inc. 142 Fairbanks Road Oak Ridge, TN 37830	Sub
HMARE	Navy	3/30/99	4/9/99	6140.001	Environmental Chemical Corporation 1240 Bayshore Highway Burlingame, CA 94010	Sub
HSAIC	DOE	8/95	9/30/96	PO# 4500012880 36-960141-53 (old#)	Science Applications International Corporation 1710 Goodridge Drive P.O. Box 133 McLean, VA 22102	Sub

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1. Robison, W.L., C.L. Conrado, and W.A. Phillips, *Enjebi Island Dose Assessment*, Lawrence Livermore National Laboratory, UCRL-53805, July 1987.

2. EPA 1989, U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A) Interim Final*, EPA/540/1-89/002, December 1989 (page 6-4).

3. EPA 1992, U.S. Environmental Protection Agency, *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, Memo from F. Henry Habicht II, Deputy Administrator to Assistant Administrators and Regional Administrators, February 26, 1992.

4. NAS 1994, National Research Council (NRC), 1994, *Radiological Assessments for Resettlement of Rongelap in the Republic of the Marshall Islands*, National Academy Press, Washington, D.C.

5. Dr. Carucci is an anthropologist who spent many years living with the people of Enewetak, and Ms. Maifeld is a Registered Dietician, who has studied the dietary patterns of the people of Enewetak.

6. See *Guidelines for Preparing Economic Analyses*. This document is currently an EPA review draft that is undergoing review by the EPA Science Advisory Board and the chapters on valuation may undergo revision.

7. See *Establishment of Cleanup levels for CERCLA Sites with Radioactive Contamination*, OSWER No. 9200.4-18, August 22, 1997.

8. See 40 CFR 300, National Contingency Plan

9. LLL recommended applying potassium chloride to soil as a means to suppress the uptake of Cs-137 by food crops on the islands.

10. U.S. Atomic Energy Commission (AEC), 1973, *Enewetak Radiological Survey*, NVO-140, Nevada Operations Office, Las Vegas, NV.

11. U.S. Department of Energy (DOE), 1982, *Enewetak Radiological Support Project, Final Report,* Friesen, B. Editor, Report NVO-213, Nevada Operations Office, Las Vegas, NV.

12. Defense Nuclear Agency (DNA), 1981, *The Radiological Cleanup of Enewetak Atoll*, Washington, D.C.

13. Bikini Atoll Rehabilitation Committee (BARC), Report No. 1, *Resettlement of Bikini Atoll: Feasibility and Estimated Cost of Meeting the Federal Radiation Protection Standards*, Submitted to the U.S. Congress House and Senate Committees on Interior Appropriations, pursuant to Public Law 97-257; 15 November 1984.

14. These are special radiological issues specific to Enewetak Atoll that arose as a result of prior cleanup activities and weapons testing that resulted in the dispersal of plutonium fragments.

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